Title: RUMBLE STRIPS RESPONSIVE SYSTEMS
Inventor(s): Hiroshi KAWAZOE et al.
DOCKET NO.: 032915-0139

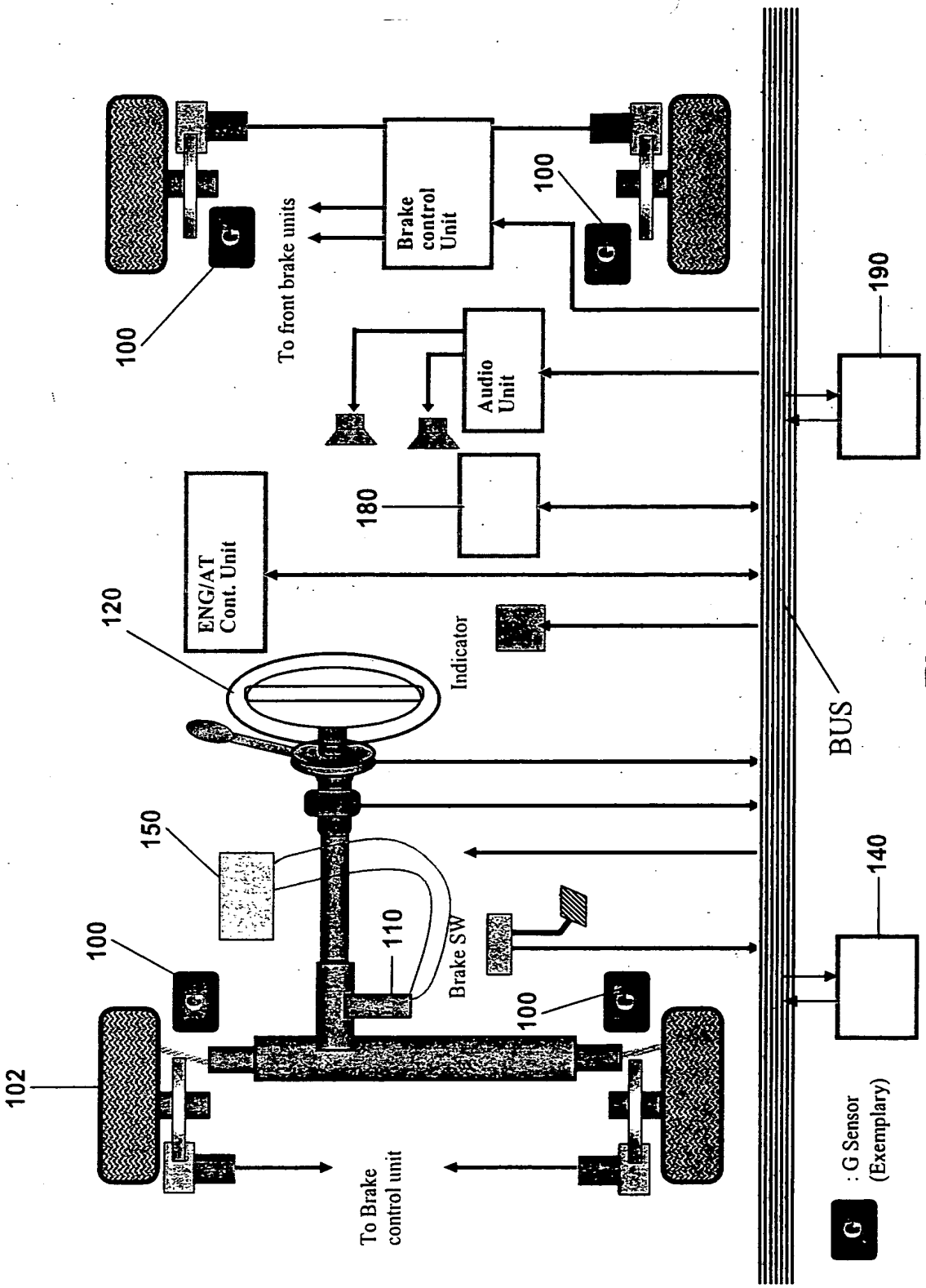


Fig.1

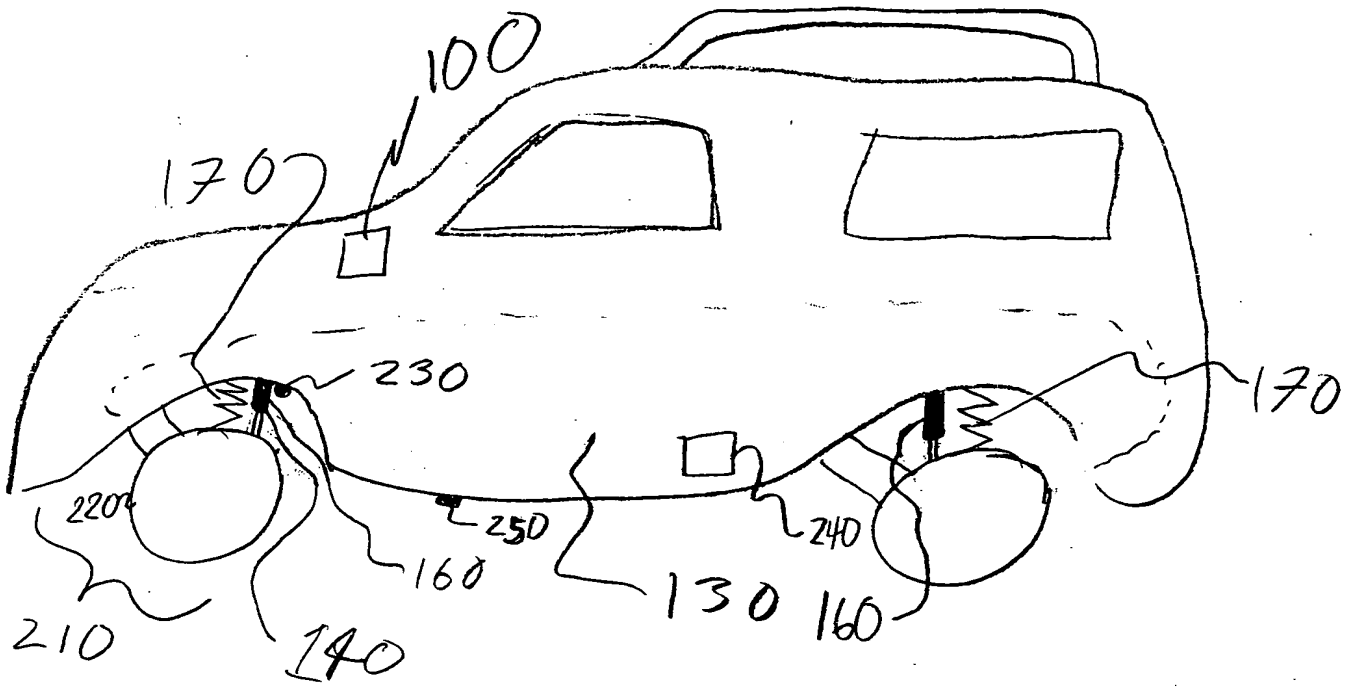


Fig. 2

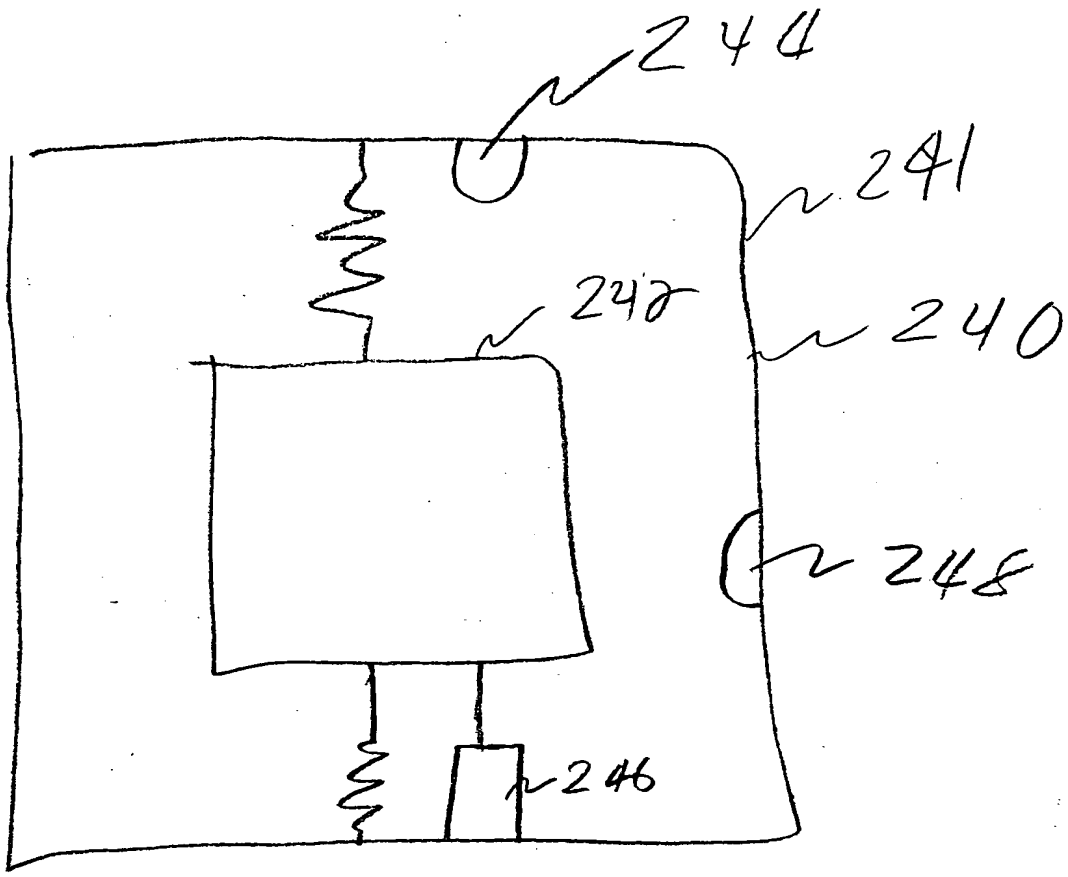


Fig. 3

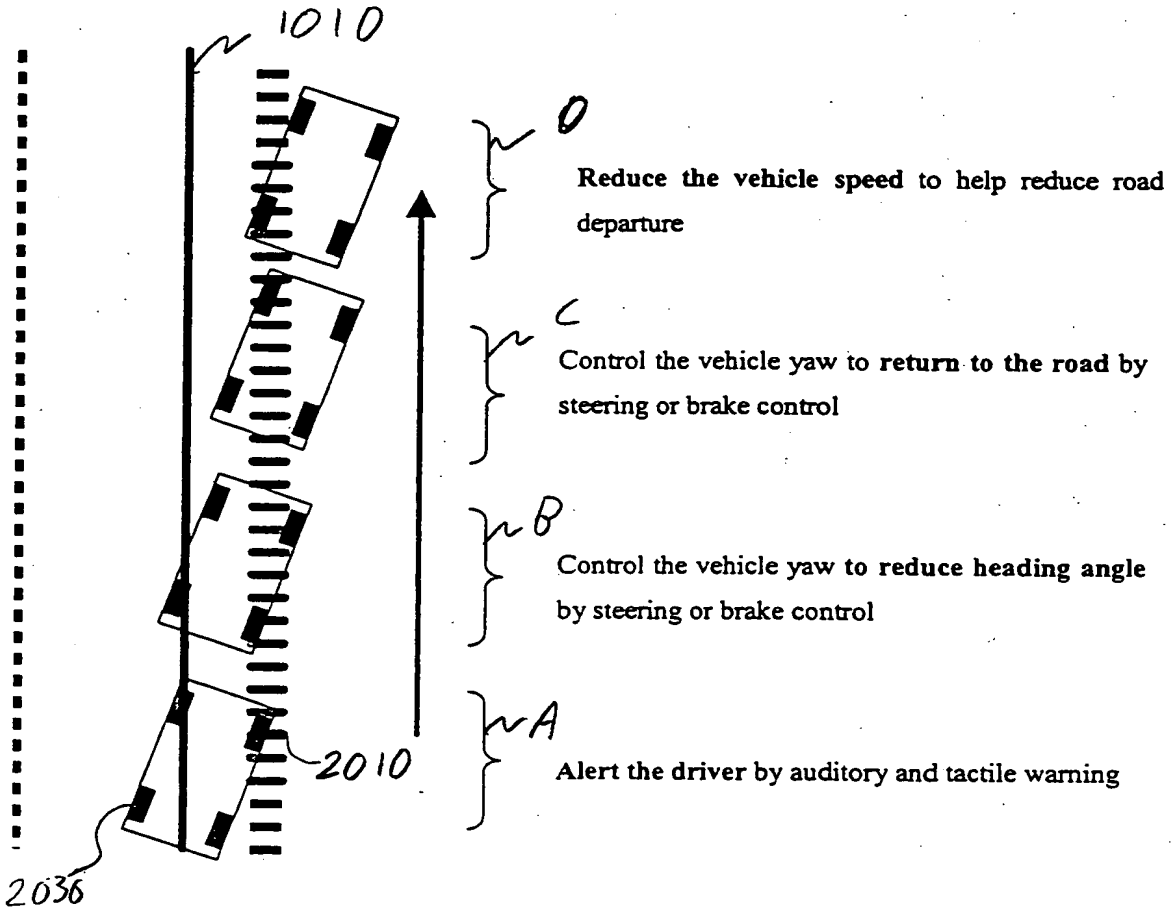
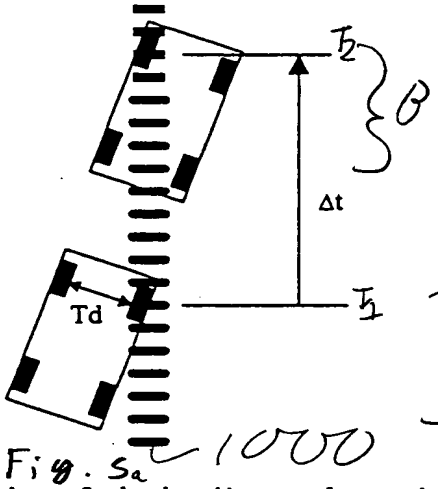

1010
D
Reduce the vehicle speed to help reduce road departure
C
Control the vehicle yaw to return to the road by steering or brake control
B
Control the vehicle yaw to reduce heading angle by steering or brake control
A
Alert the driver by auditory and tactile warning
2010
2036

Fig. 4

Calculation of the Lateral speed at Deviation



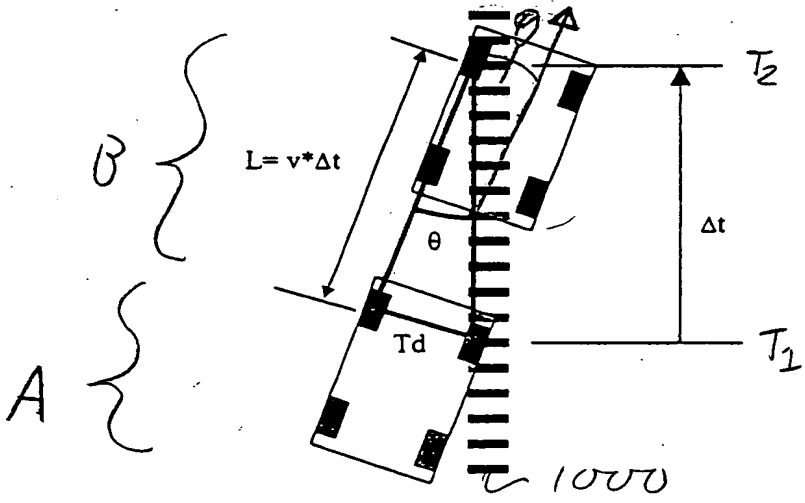
Dv=Td/Δt [m/s]

Td ; Tread distance

Dv ; Lateral speed

Fig. 5a

Calculation of the heading angle at deviation



tanθ= Td/L = Td/(v*Δt)

Td ; Tread distance

v ; Vehicle Speed

Fig. 5b

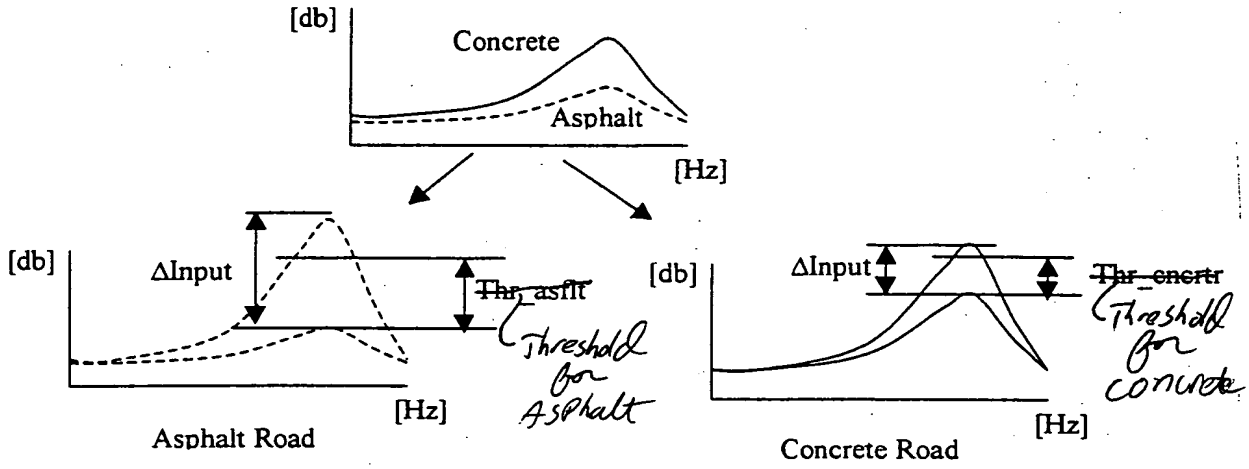

[db]
Concrete
Asphalt
[Hz]
[db]
ΔInput
Thr_asflt
Threshold for Asphalt
[Hz]
Asphalt Road
[db]
ΔInput
Thr_cncrtr
Threshold for concrete
[Hz]
Concrete Road

Fig. 6

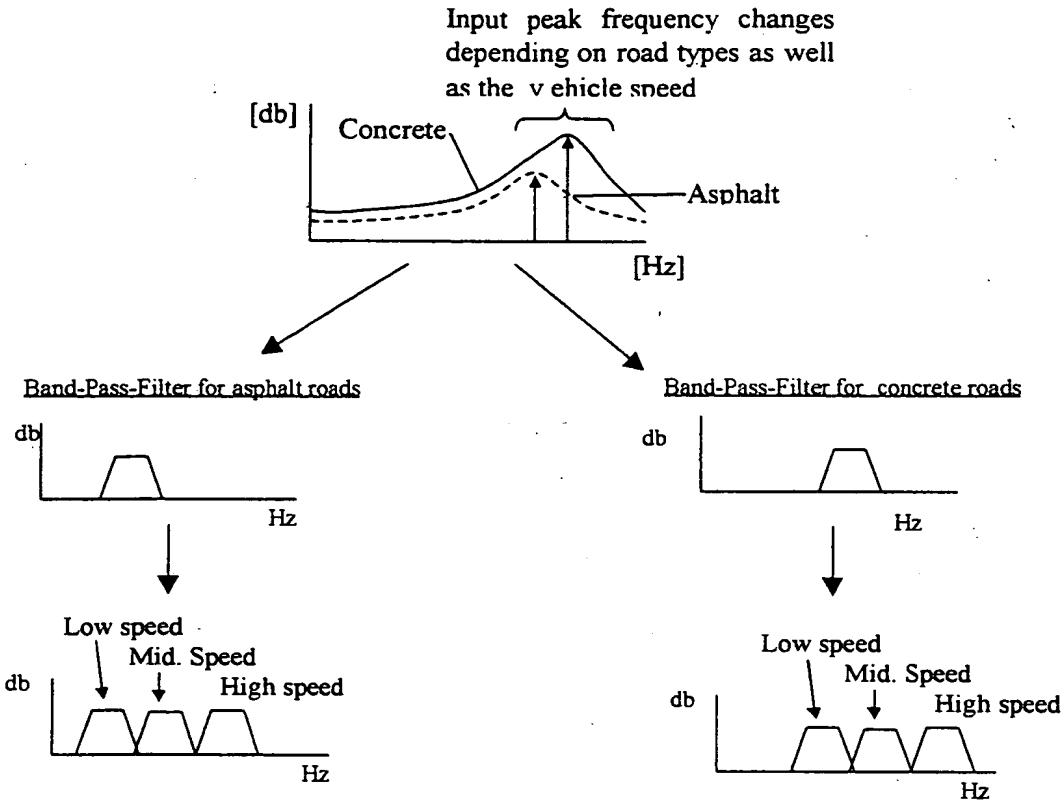
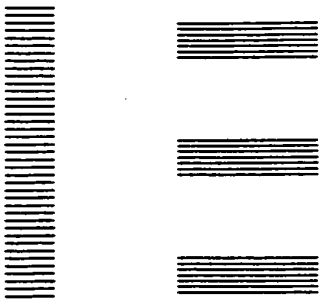

Input peak frequency changes depending on road types as well as the vehicle speed
[db]
Concrete
Asphalt
[Hz]
Band-Pass-Filter for asphalt roads
db
Hz
Low speed
Mid. Speed
High speed
db
Hz
Band-Pass-Filter for concrete roads
db
Hz
Low speed
Mid. Speed
High speed
db
Hz

Fig. 7



Continuous RS Intermittent RS

Fig. 8

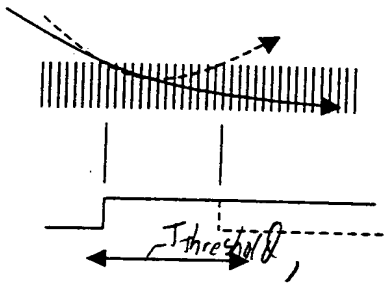


Fig. 9

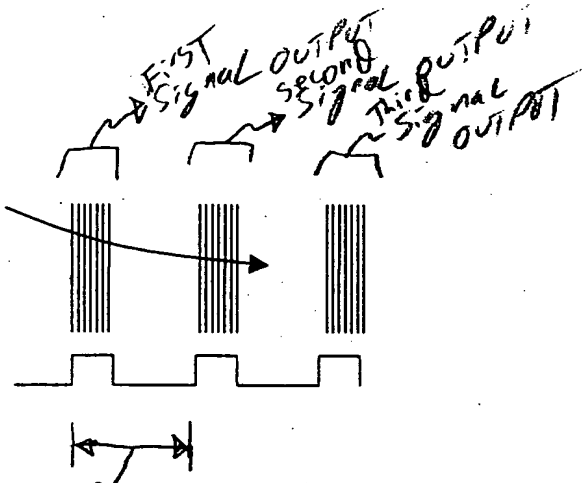


Fig. 10

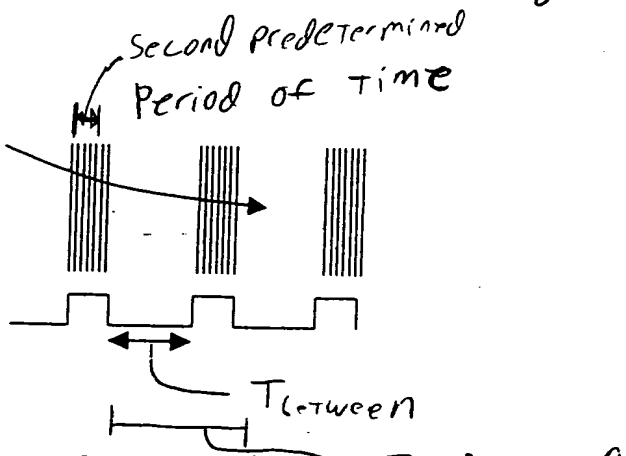


Fig. 11

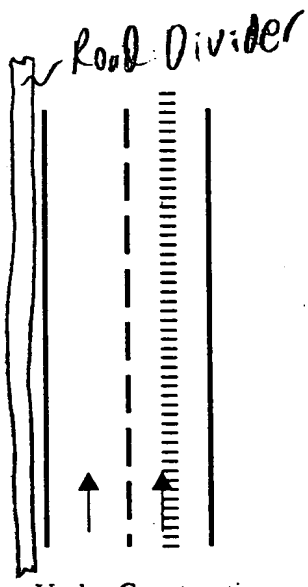


Fig. 12

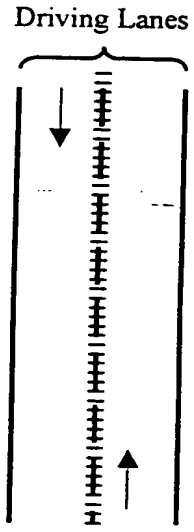


Fig. 13

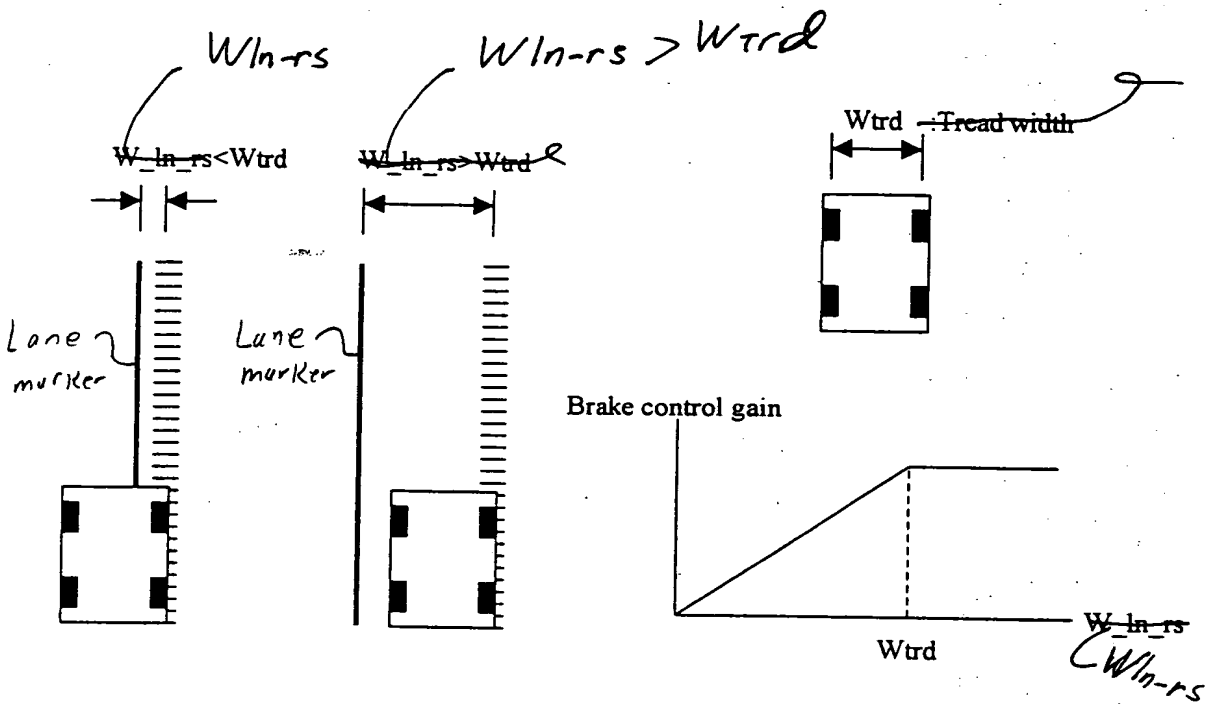

Wln-rs
Wln-rs > Wtrd
W_ln_rs<Wtrd
W_ln_rs>Wtrd
Wtrd
Tread width
Lane marker
Lane marker
Brake control gain
W_ln_rs
Wtrd
Wln-rs

Fig. 14

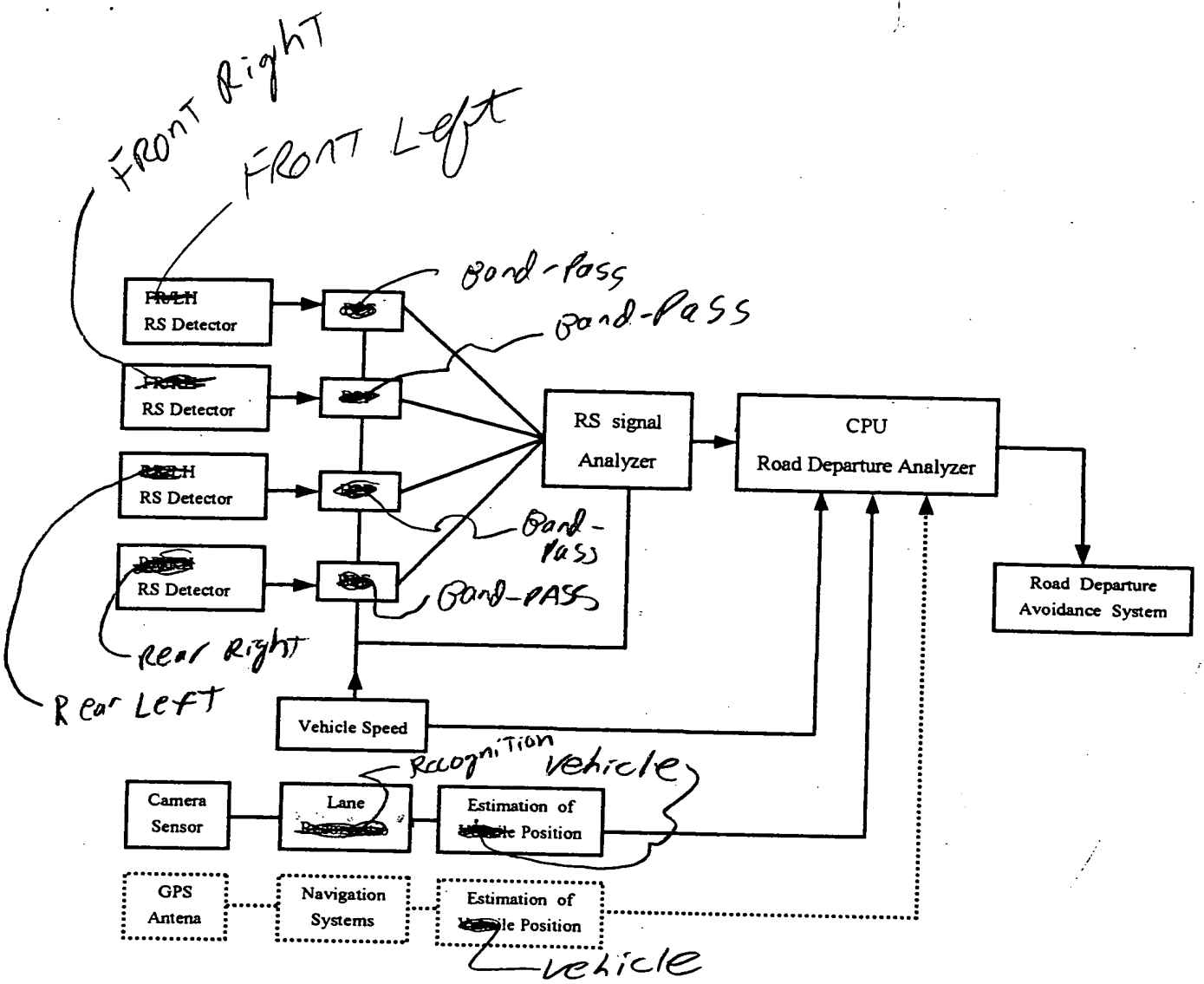

FRONT Right
FRONT Left
RS Detector
RS Detector
RS Detector
RS Detector
Band-Pass
Band-Pass
Band-
Pass
Band-PASS
RS signal Analyzer
CPU
Road Departure Analyzer
Road Departure Avoidance System
Rear Right
Rear Left
Vehicle Speed
Recognition
Vehicle
Camera Sensor
Lane
Estimation of
Position
GPS Antena
Navigation Systems
Estimation of
Position
Vehicle

Fig. 15

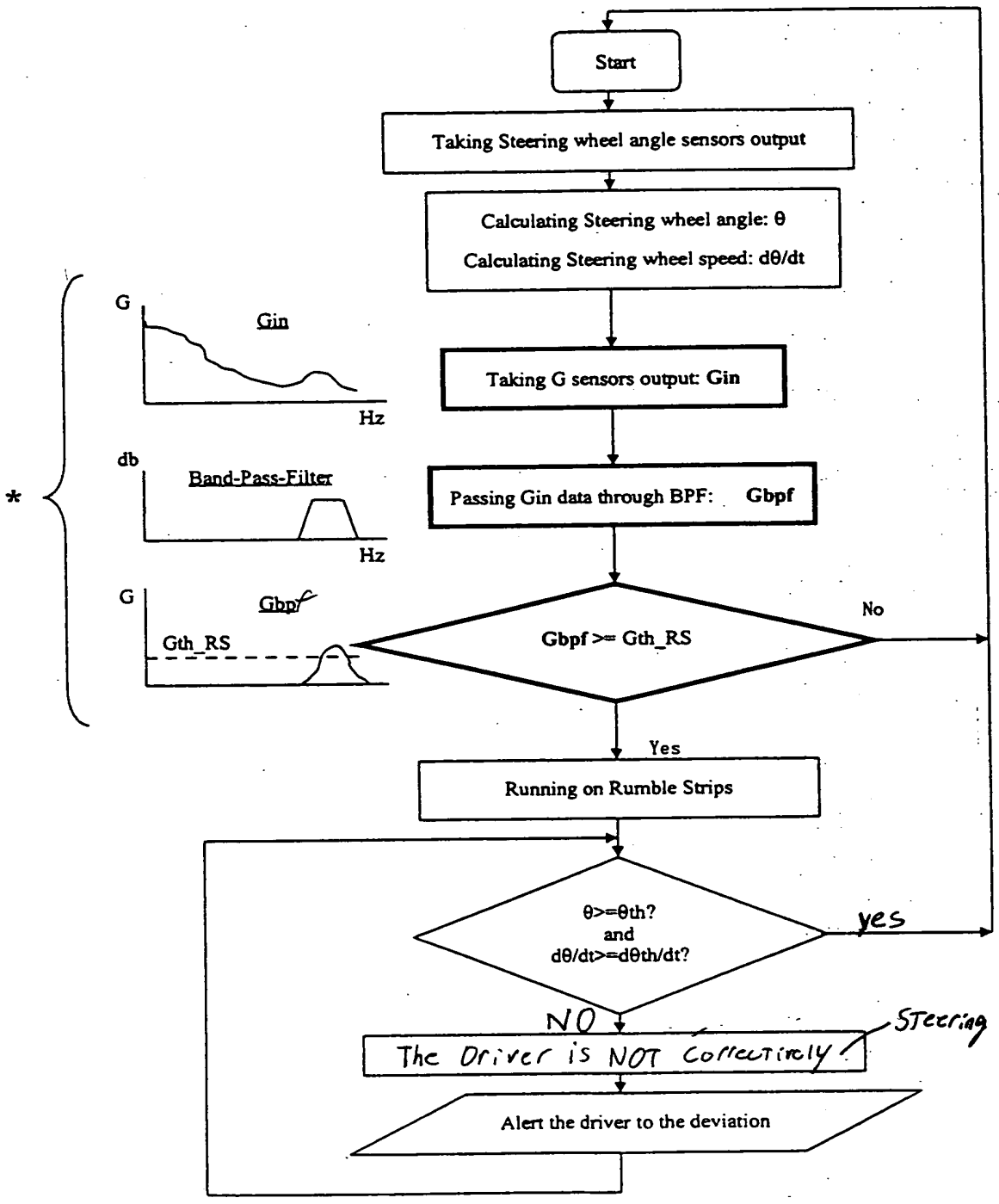

Start
Taking Steering wheel angle sensors output
Calculating Steering wheel angle: θ
Calculating Steering wheel speed: dθ/dt
Taking G sensors output: Gin
Passing Gin data through BPF: Gbpf
Gbpf >= Gth_RS
No
Yes
Running on Rumble Strips
θ>=θth? and dθ/dt>=dθth/dt?
yes
NO
The Driver is NOT Correctly Steering
Alert the driver to the deviation
G
Gin
Hz
db
Band-Pass-Filter
Hz
G
Gbpf
Gth_RS
*

Fig. 16

Exemplary

Cut-off frequencies of Band-Pass Filter in response to vehicle speed

The pattern of rumble strips: cycle distance ; 30.48cm (1foot)

140~ km/h 128 Hz BPF#1

120~140km/h 109 Hz BPF#2

100~120km/h 91 Hz BPF#3

80~100km/h 72 Hz BPF#4

60~80km/h 55 Hz BPF#5

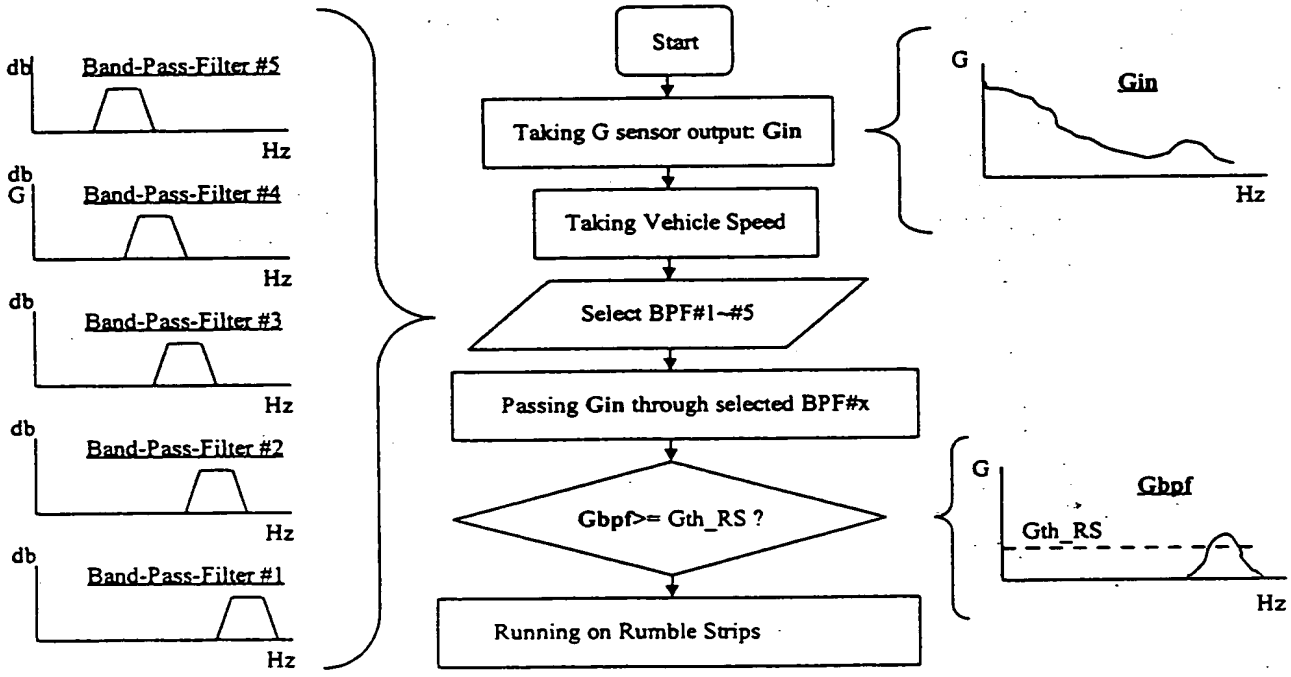


Fig. 17

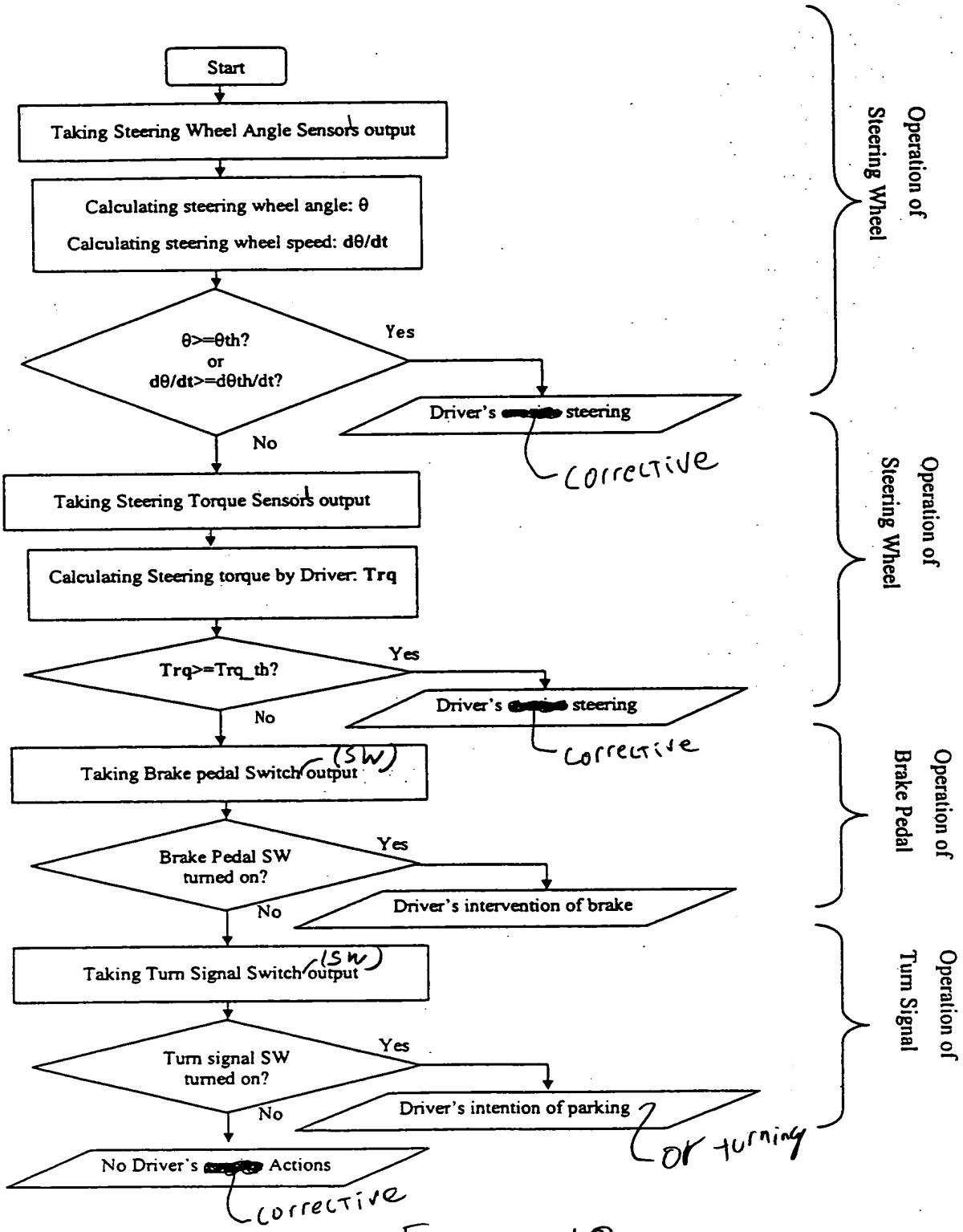

Start
Taking Steering Wheel Angle Sensors output
Calculating steering wheel angle: θ
Calculating steering wheel speed: dθ/dt
θ>=θth?
or
dθ/dt>=dθth/dt?
Yes
No
Driver's [redacted] steering
corrective
Taking Steering Torque Sensors output
Calculating Steering torque by Driver: Trq
Trq>=Trq_th?
Yes
No
Driver's [redacted] steering
corrective
Taking Brake pedal Switch output (SW)
Brake Pedal SW turned on?
Yes
No
Driver's intervention of brake
Taking Turn Signal Switch output (SW)
Turn signal SW turned on?
Yes
No
Driver's intention of parking or turning
No Driver's [redacted] Actions
corrective
Operation of Steering Wheel
Operation of Steering Wheel
Operation of Brake Pedal
Operation of Turn Signal

Fig. 18

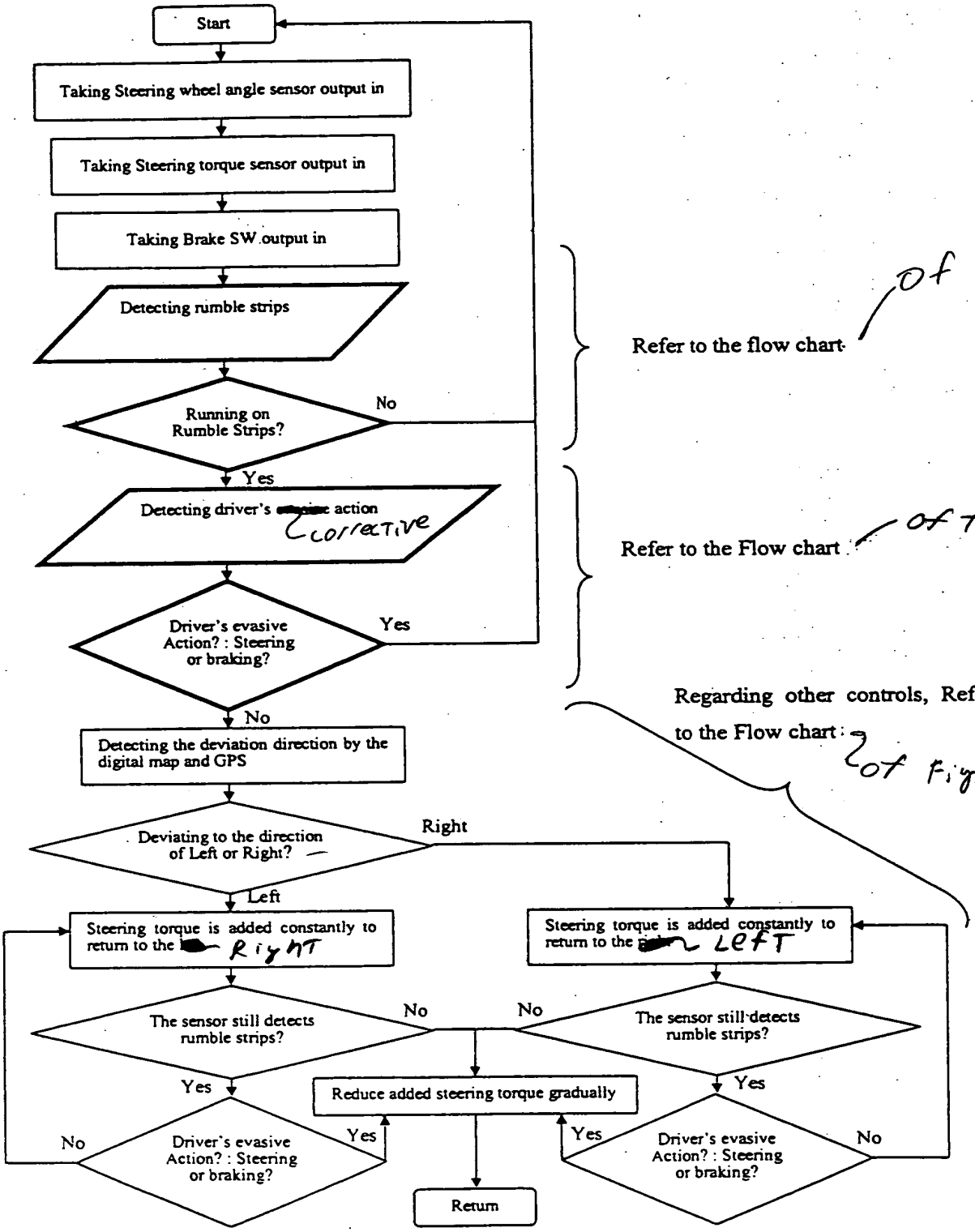

Start
Taking Steering wheel angle sensor output in
Taking Steering torque sensor output in
Taking Brake SW output in
Detecting rumble strips
Running on Rumble Strips?
No
Yes
Detecting driver's corrective action
Driver's evasive Action? : Steering or braking?
Yes
No
Detecting the deviation direction by the digital map and GPS
Deviating to the direction of Left or Right?
Right
Left
Steering torque is added constantly to return to the Right
Steering torque is added constantly to return to the Left
The sensor still detects rumble strips?
No
No
The sensor still detects rumble strips?
Yes
Yes
Reduce added steering torque gradually
No
Driver's evasive Action? : Steering or braking?
Yes
Yes
Driver's evasive Action? : Steering or braking?
No
Return
Refer to the flow chart of Fig. 17
Refer to the Flow chart of Fig 18
Regarding other controls, Refer to the Flow chart of Fig 5. 20 and 21

Fig. 19

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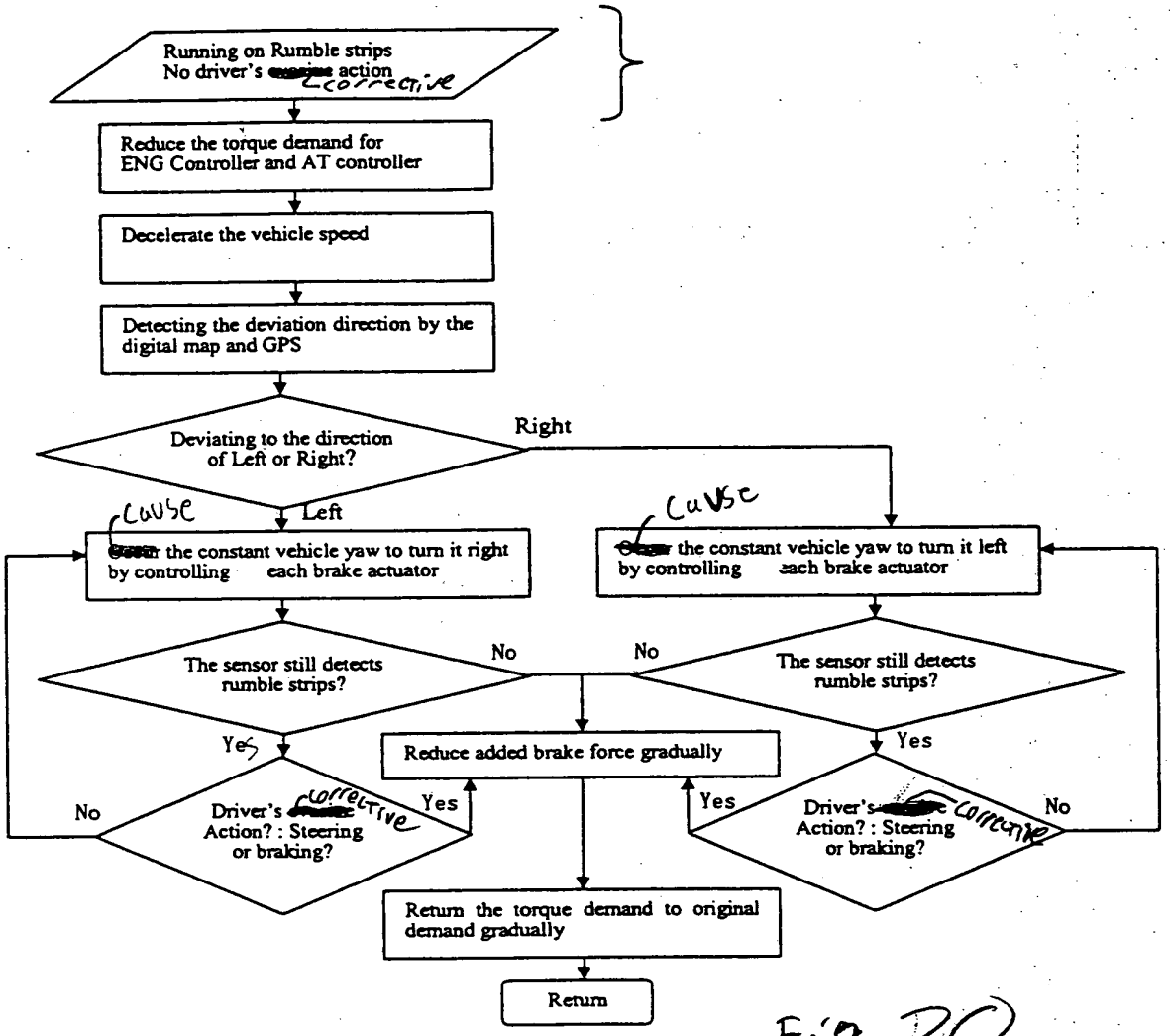


Fig. 20

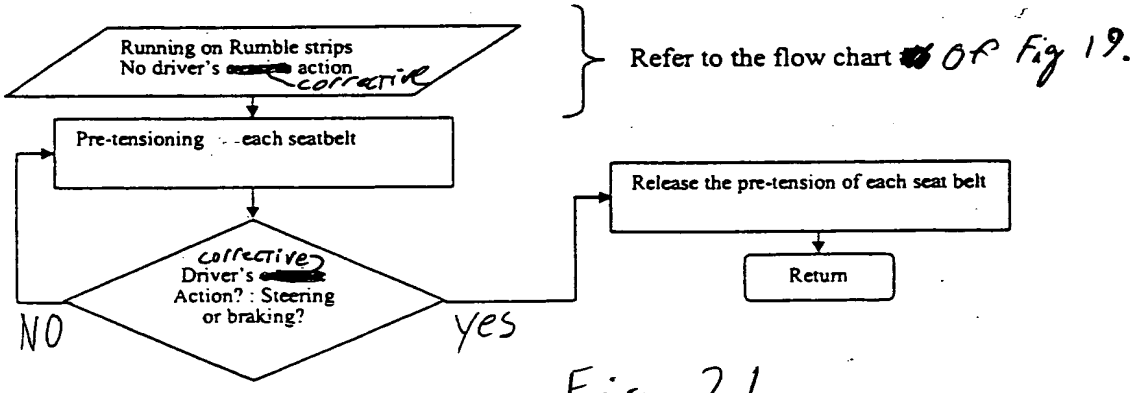
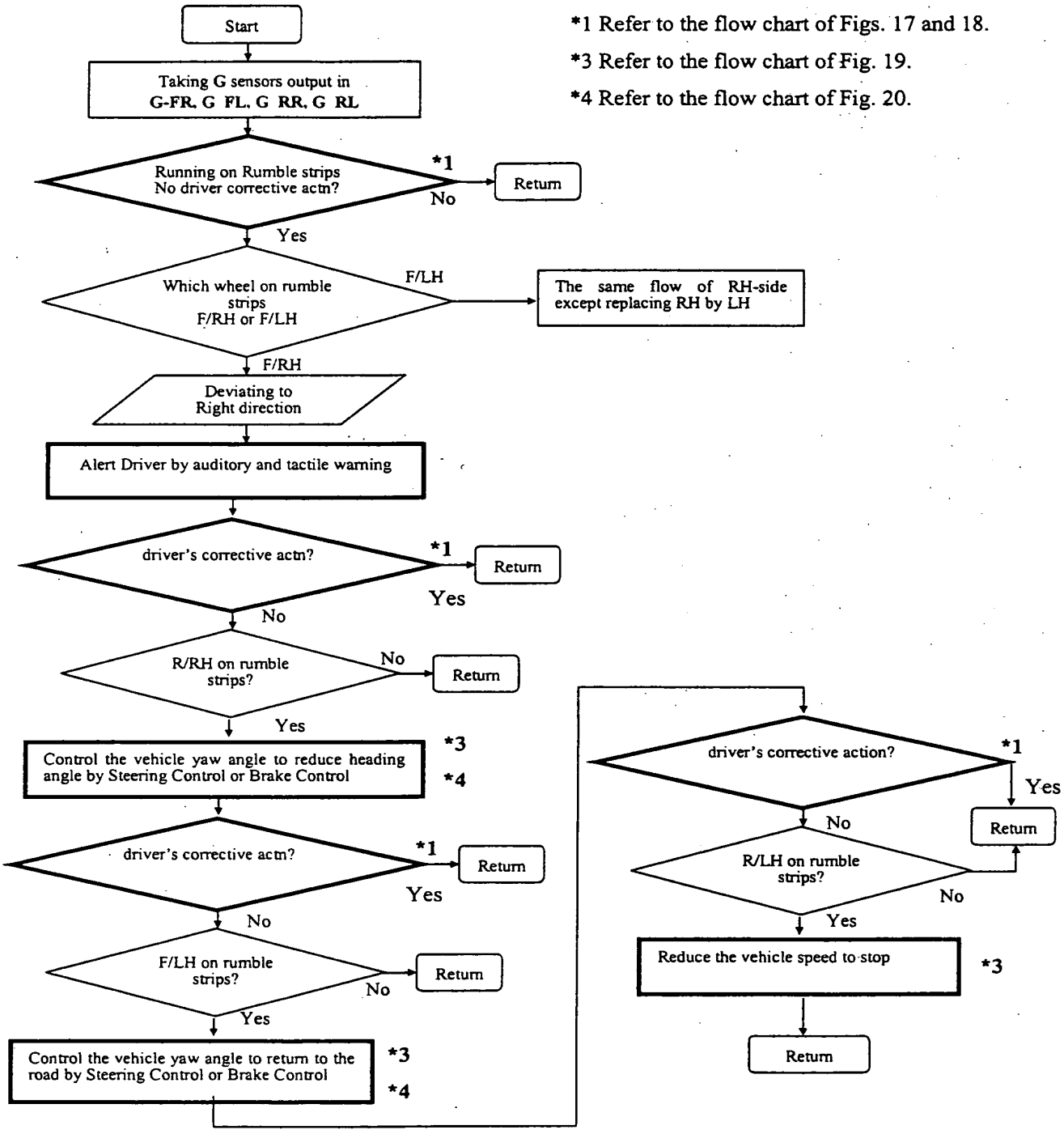


Fig. 21



*1 Refer to the flow chart of Figs. 17 and 18.

*3 Refer to the flow chart of Fig. 19.

*4 Refer to the flow chart of Fig. 20.

Fig. 22

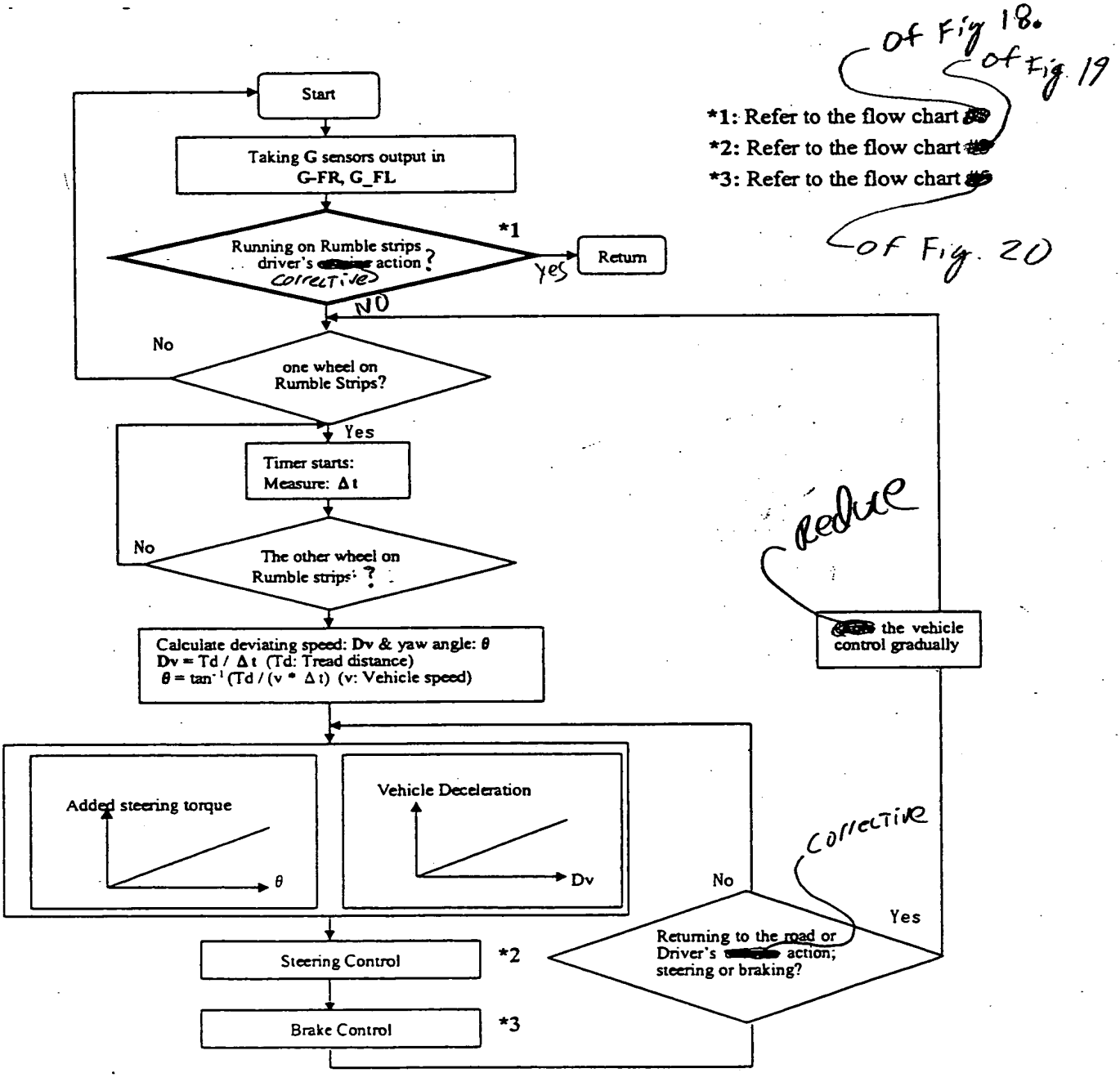

of Fig 18.
of Fig 19
*1: Refer to the flow chart
*2: Refer to the flow chart
*3: Refer to the flow chart
of Fig. 20
Start
Taking G sensors output in G-FR, G_FL
*1
Running on Rumble strips driver's action? corrective
Yes
Return
NO
No
one wheel on Rumble Strips?
Yes
Timer starts: Measure: Δt
No
The other wheel on Rumble strips?
Calculate deviating speed: Dv & yaw angle: θ
Dv = Td / Δt (Td: Tread distance)
θ = tan⁻¹ (Td / (v * Δt) (v: Vehicle speed)
Added steering torque
θ
Vehicle Deceleration
Dv
Steering Control
*2
Brake Control
*3
reduce
the vehicle control gradually
corrective
No
Yes
Returning to the road or Driver's action; steering or braking?

Fig. 23

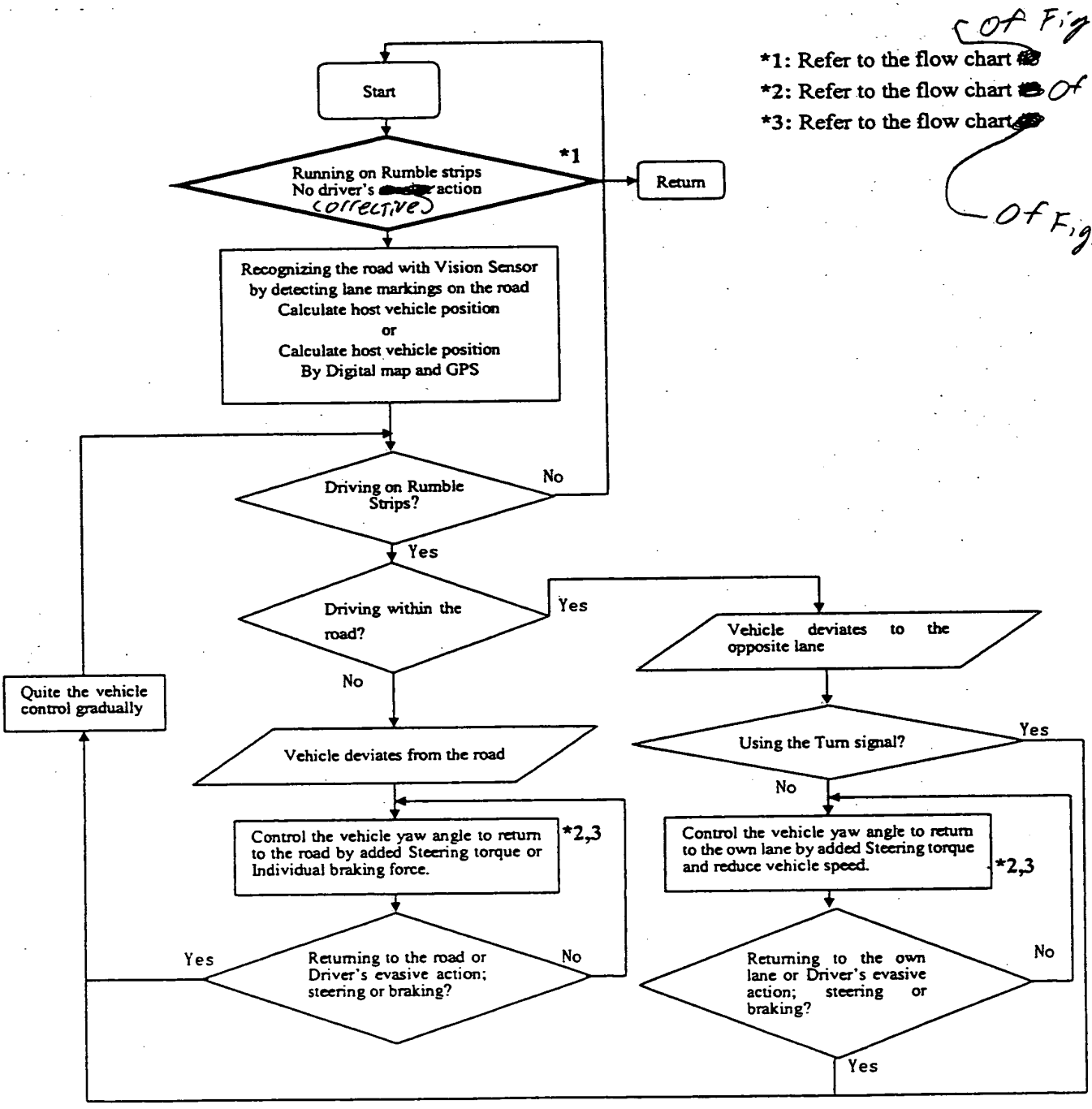
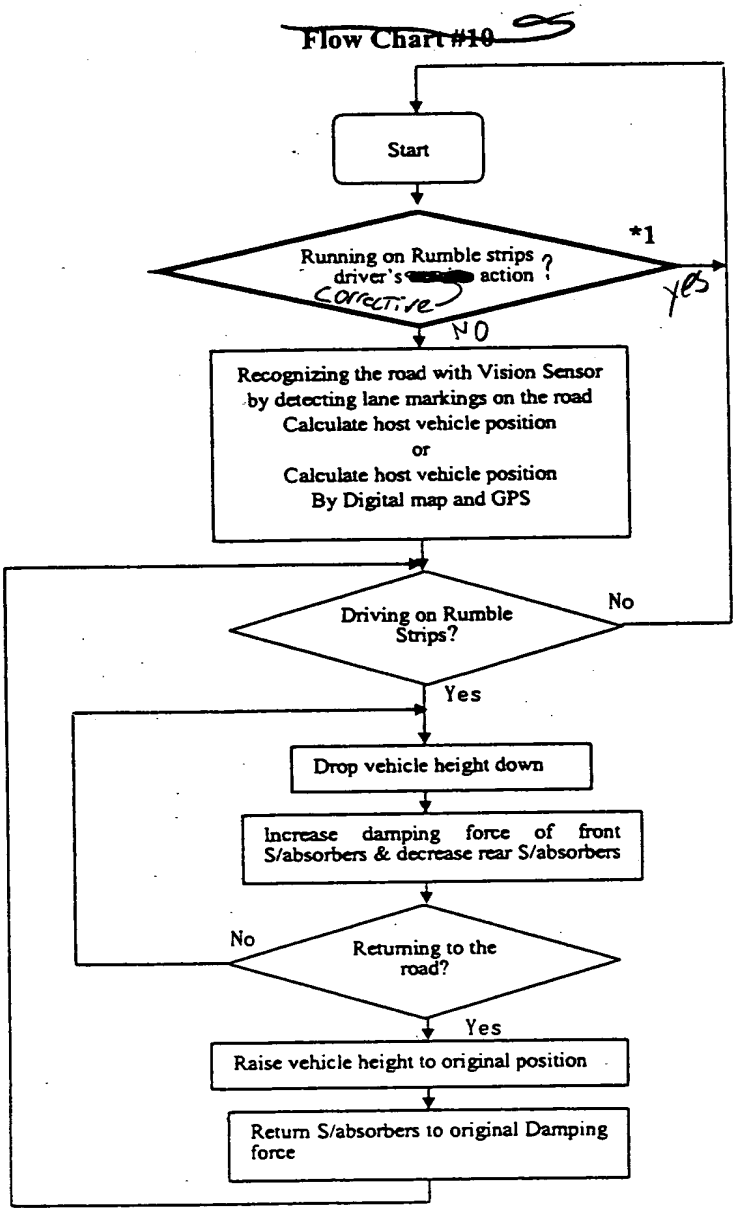

Start
Running on Rumble strips
No driver's corrective action
*1
Return
Recognizing the road with Vision Sensor
by detecting lane markings on the road
Calculate host vehicle position
or
Calculate host vehicle position
By Digital map and GPS
Driving on Rumble Strips?
No
Yes
Driving within the road?
Yes
No
Vehicle deviates to the opposite lane
Quite the vehicle control gradually
Vehicle deviates from the road
Using the Turn signal?
Yes
No
Control the vehicle yaw angle to return to the road by added Steering torque or Individual braking force.
*2,3
Control the vehicle yaw angle to return to the own lane by added Steering torque and reduce vehicle speed.
*2,3
Returning to the road or Driver's evasive action; steering or braking?
Yes
No
Returning to the own lane or Driver's evasive action; steering or braking?
No
Yes
*1: Refer to the flow chart of Fig. 19
*2: Refer to the flow chart of Fig. 19
*3: Refer to the flow chart of Fig. 20

Fig. 24



*1: Refer to the flow chart of Fig. 18

Fig. 25